STAFF SUMMARY
Method 2B Application for
Brazilian Sugarcane Molasses-to-Ethanol LCFS Pathway
Abengoa Bioenergia Agroindustria Ltda
São Luiz Facility, Pirassununga (Sao Paulo), Brazil

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Pathway Summary

Abengoa Bioenergia Agroindustria Ltda (Abengoa Bioenergia) produces ethanol derived from sugarcane by-product molasses at their São Luiz (ABSL) integrated sugar and ethanol production facility in the City of Pirassununga, State of Sao Paulo, Brazil. Sugarcane is harvested on company- owned and partnership farms, and then transported to the ABSL sugar mill and ethanol distillery. After the sugarcane has been crushed, the cane juice is filtered, treated with calcium hydroxide, decanted, and then sent to sugar production. A by-product of the sugar production process is molasses which is the predominant feedstock sent to the ethanol distillery for fermentation and distillation, resulting in the production of anhydrous ethanol. The by-product molasses is however, not exhausted of its sucrose content and may have a higher value than molasses commonly sold as a livestock supplement.

The life cycle of the ABSL pathway begins with sugarcane cultivation and transport, followed by sugar and ethanol production. The agricultural and ethanol production phases of this pathway are identical to those described in the ARB's Brazilian sugarcane ethanol pathway.[1] The majority of the sugarcane harvested in Sao Paulo-State employs mechanical harvesters. A majority of the sugarcane produced for sugar and ethanol production is also procured from mechanically harvested ABSL owned- or partnership- sugarcane farms.

The ABSL facility also generates and utilizes process heat and electricity from bagasse combustion for all its industrial operations. Surplus electricity produced is exported to the local electrical grid. The major difference between the ABSL pathway and the Brazilian sugarcane-based ethanol pathway is the type of feedstock used for ethanol production. ABSL primarily utilizes molasses, the by-product from the sugar production process, whereas the Brazilian sugarcane ethanol pathway was based upon the use of pure sugarcane juice for ethanol production. Ethanol produced from fermentation of the molasses is transported by truck to the eastern port of Santos**,** and loaded onto ocean-going tankers for shipment to California. Ethanol transport and distribution modes in California are assumed to be identical to those used in the Brazilian sugarcane ethanol pathway.

[1] California Air Resources Board, 2009. Detailed California-Modified GREET Pathways for Brazilian Sugarcane Ethanol: Average Brazilian Ethanol, With Mechanized Harvesting and Electricity Co-product Credit, With Electricity Co-product Credit, version 2.3, September 23, 2009. http://www.arb.ca.gov/fuels/lcfs/092309lcfs_cane_etoh.pdf

Facility Location and Coordinates

The Abengoa São Luiz sugar mill and ethanol production facility is located in the City of Pirassununga within the State of Sao Paulo, Brazil. The geographic coordinates of the centroid of the ethanol distillery, shown in the satellite view below, are 21°53'15" S (latitude), and 47°18'30" W (longitude).

Satellite View of Abengoa Bioenergia
São Luiz Sugar and Ethanol Production Facility
Pirassununga, Sao Paulo, Brazil

Carbon Intensity of the ABSL Pathway

ARB staff has assessed the inputs used by ABSL to determine its well-to-wheels (WTW) pathway carbon intensity. As sugar and molasses are products of the same agricultural, feedstock transport, and sugar production processes, the GHG emissions from these activities must be allocated between the two products. The allocation method chosen by Abengoa Bioenergia is the mass-based allocation methodology in which the total upstream and sugar production emissions are allocated on the basis of

the ratio of the total reduced sugars (TRS)[2] in the molasses entering the ethanol distillery to the total reduced sugars that enter the sugar production process for each metric tonne of sugarcane that enters the factory gate.

Based on the mass ratio of the TRS in by-product molasses per tonne of sugarcane to the TRS in the post-crush sugarcane juice stream per tonne of sugarcane, ABSL has determined that 21.18 grams of carbon dioxide-equivalent emissions per mega joule (gCO_2e/MJ fuel) of upstream and sugar production emissions should be allocated to the production of the by-product molasses. When these upstream and sugar production emissions are combined with ethanol production, addition of denaturant, transport, and distribution emissions, the total well-to-tank (WTT) life cycle GHG emissions for the ABSL pathway are estimated to be 29.73 gCO_2e/MJ fuel. This WTT estimate includes the credit for mechanized harvesting (which offsets the straw burning emissions) but not the co-product credit for exports of surplus cogenerated electricity.

The ABSL mill exports surplus cogenerated electricity to the public grid. Due to the use of by-product molasses as a feedstock for ethanol production, the applicable electricity cogeneration export credit must be calculated differently however. The reason is that, when all of the sugarcane juice is sent to sugar production, the sugarcane bagasse that is generated after the cane crush is assumed to belong to the sugar mill. Since only the by-product of the sugar production process is fermented into ethanol, the credit is therefore assumed to be proportional to the fraction of fermentables (TRS) in by-product molasses to the total amount of fermentables[3] (TRS) in the pure sugarcane juice, measured after the cane crush. In other words, the mass allocation methodology used to allocate upstream emissions is also used to determine the quantity of surplus cogenerated electricity exports that should be credited to the by-product molasses pathway. The resulting electricity cogeneration and surplus export credit, based on a displacement of Brazilian marginal electricity rate of 2.85 kWh per gallon of ethanol produced, is estimated to be 20.81 gCO_2e/MJ of fuel produced. When applied to the WTT carbon intensity (CI) of ethanol, this credit results in a net WTT CI of 8.92 gCO_2e/MJ. When life cycle emissions due to land use change (LUC) of 46 gCO_2e/MJ are added to the WTT CI estimate, the final WTW CI for the ABSL pathway is estimated to be 54.92 gCO_2e/MJ of ethanol fuel produced. Despite the allocation of some upstream emissions to the sugar production process, this change results in a CI for the ABSL pathway that is comparable to that of sugarcane juice-derived ethanol. A summary of the disaggregated CI estimate for the ABSL pathway is presented in Table 1 below.

[2] The applicant has based the fermentable sugar balance for the ABSL pathway on the ART (total recoverable sugars) parameter analyzed from laboratory quality data.

[3] This ratio was found to be 0.26. It is the same mass allocation factor for estimating the contribution to the ABSL pathway from upstream emissions.

Table 1: Summary of Disaggregated WTW GHG Emissions for the ABSL By-Product Molasses-to-Ethanol Pathway

Disaggregated Item	Value Reference	Total Sugar Production GHG Emissions: (g CO_2e/metric tonne cane)	GHG Emissions Allocated to ABSL Pathway: (g CO_2e/MJ)
Well-to-Tank (WTT) Allocated GHG Emissions:		***ABSL Mass Allocation Factor: 0.26***	
Sugarcane Farming	See Worksheet* "Cane Farming Abengoa Inputs"	7,732	4.17
Agricultural Chemicals Use	See Worksheet* "Cane Farming Abengoa Inputs"	16,556	8.93
Straw Burning Emissions	See Worksheet*"Straw Burning"	15,481	2.30
- Less Credit for Mechanized Harvesting	Mechanized Harvesting Fraction based upon 2012-2014 Data	(11,214)	-
Sugarcane Transport	See Worksheet* "T&D"	3,792	2.04
Sugarcane Material Handling and Supplemental Fuel Use	See Worksheet "EtOH Prod"		1.54
Sugar Production	See Worksheet* "Allocation"	4,079	2.20
Additional Lime (CaO) Use for Juice pH Adjustment	(Seabra et al, 2011)[4]	-	0.60
Total Upstream GHG Emissions:		-	**21.18**
Ethanol Production	See Worksheet "EtOH Prod"	-	2.40
Ethanol Transport & Distribution	See Worksheet "T&D"	-	4.74
Addition of Denaturant	Indonesian Molasses Pathway	-	0.80
Well-to-Tank (WTT) GHG Emissions Estimate Before Electricity Export Credit:		-	***29.73***
Electricity Cogeneration and Surplus Export Credit	See Worksheet "Cogen Exp Cr"	-	(20.81)
Total Well-to-Tank (WTT) CI Estimate:		-	**8.92**
Land Use Changes	Brazilian Sugarcane Ethanol (See Footnote 1).		46.00
Final Well-to-Wheel (WTW) CI Estimate:			**54.92**

*See spreadsheet entitled "Final ABSL CI Disaggregation Analysis_Redacted.xlsx" in link "Supporting Information."

[4] *Seabra et al. "Life cycle assessment of Brazilian sugarcane products: GHG emissions and energy use," Seabra, J.E.A., Macedo, I.C., Chum, H.L., Faroni, C.E., and Sarto,C.A., Biofuels, Bioproducts, & Biorefining, 5:519-532, March 7, 2011.*

A mass-based allocation factor was used to adjust the ILUC increment downward in the previous Indonesian and Central American sugarcane byproduct molasses-to-ethanol pathways. The full yield of ethanol from sugarcane juice per metric tonne of sugarcane was used in the denominator of this allocation factor to reflect the dynamics of the sugar and molasses markets in Indonesia and Central America. While sugar is a relatively high-valued export commodity in these regions, molasses was historically sold into local livestock feed markets (its value is too low to justify exports). The use of by-product molasses as an ethanol feedstock increases its value, but changes in the value of a by-product can only have a limited effect on the production of the primary product. Hence, the increase in the value of by-product molasses as an ethanol feedstock will have a limited effect on the amount of land brought into sugar cane cultivation. The demand for ethanol produced directly from sugar cane juice, on the other hand, directly drives the amount of land under sugar cane cultivation. When used as ethanol feedstocks, therefore, sugar cane juice and molasses will not have equal effects on the amount of land brought into sugar cane cultivation, and only a fraction of the ILUC could be apportioned to by-product molasses.

Staff however, re-evaluated the extent to which the Brazilian sugar, ethanol, and molasses markets are similar to the Indonesian and Central American markets. The result was a finding that the markets in which ABSL operates bears little similarity to the corresponding Indonesian and Central American markets. The primary differences are (a) that molasses is produced exclusively as an ethanol feedstock for use within the integrated sugar and ethanol production complex (no outside market for molasses exists, and (b) that the feedstock molasses used in the ABSL mill is not "exhausted" molasses like that used in Indonesia and Central America. These differences indicate the molasses used in the ABSL mill can have a significant effect on the demand for cane juice and, by extension, the amount of land under sugar cane cultivation. There is no basis, therefore, for reducing the contribution of ILUC to the carbon intensity (CI) of the ABSL by-product molasses pathway. Therefore, staff will require that the ABSL pathway (and others like it in the future) include the full sugar cane ethanol land use change estimate of 46 gCO_2e/MJ. The proposed Lookup Table entry for the ABSL pathway is presented in Table 2 below:

Table 2: Proposed Lookup Table Entry for Fuel/Feedstock

Fuel	Pathway Identifier	Pathway Description	Carbon Intensity Values (gCO_2e/MJ)		
			Direct Emissions	Land Use or Other Indirect Effects	Total
Ethanol	ETHM010	2B Application*: Brazilian sugarcane by-product molasses-based ethanol with average production processes, and credit for export of surplus cogenerated electricity, and mechanized harvesting.	8.92	46.00	54.92

*Specific Conditions Apply.

Applicable Operating Conditions

Operations at the ABSL plant will be subject to the following conditions designed to ensure that the CI of the by-product molasses-based ethanol sold under the pathway described in this Staff Summary will remain at or below the value appearing in Table 2. The conditions must be met for every gallon of ethanol sold by ABSL in California. Exceptions are allowable only in the case of brief periods of planned maintenance or unpredictable, unavoidable, and uncontrollable force majeure events.

1. In order for ABSL to sell ethanol in California using the fuel pathway described in this document, only the by-product molasses from ABSL's sugar production process may be used as feedstock for the ethanol plant. By-product molasses is the by-product of the sugar production process and has the approximate quality and ethanol yield of 85°Brix, and 91.7 gallons ethanol per metric tonne of molasses(347 liters ethanol per metric tonne of molasses), respectively.

2. The mass allocation ratio as determined from the mass flow rate of total reduced sugars (fermentables) in by-product molasses per tonne of sugarcane being sent to the ethanol distillery to the mass-flow rate of the total reduced sugars in the pure post-crush sugarcane juice stream per tonne of sugarcane, shall not exceed 0.26.

3. The CI for ethanol produced by the ABSL pathway is based on the allocation factor Abengoa Bioenergia applied to upstream emissions from sugarcane farming, agricultural chemical use, the estimated fraction of in-field straw burning, sugarcane transport, and sugar production. ABSL's allocation factor is identified in the worksheet "Allocation."[5] If any of the input assumptions or parameters used to determine the allocation factor are changed, the CI estimate may no longer be valid. ARB must be notified of such changes as they occur, and their impacts on the ethanol fuel CI must be re-assessed.

4. The CI for ethanol produced by the ABSL pathway includes a credit for electricity cogeneration and surplus exports. If the bagasse is used for any purpose other than cogeneration of electricity, or if additional bagasse is brought into the facility for cogeneration from outside the ABSL mill, or if the boilers are de-rated, then the CI for the ethanol produced may no longer be valid and must be reassessed.

Staff Analysis and Recommendations

Staff has reviewed Abengoa Bioenergia's application for certification of a Brazilian sugarcane by-product molasses-based ethanol pathway for its São Luiz facility and finds the following:

[5] See spreadsheet entitled "Final Staff Disaggregation Analysis for ABSL.xlsx" posted in link "Supporting Information."

- Staff has replicated with reasonable accuracy, using a mass-based allocation methodology, the CA-GREETv1.8b GHG lifecycle emissions modeling spreadsheet, and other input process parameters furnished by ABSL, the CI value being proposed for certification.

- Staff recognizes that the plant energy (process heat and electricity) consumption values reported for ABSL's process reflect cogeneration activities from bagasse combustion with surplus electricity export to the public grid. In addition, the pathway well-to-tank GHG emissions analysis reflects applicable credits for the use of mechanized harvesting practices at the sugarcane farms.

- Staff agrees that the mass-based method used to allocate GHG emissions to the upstream sugarcane farming, transport, and sugar production processes is valid and representative for the ABSL pathway being proposed for adoption.

- Staff proposes an interim approach to estimate the impact of indirect land use change (ILUC) emissions for this pathway based upon the ILUC estimate for ethanol derived from pure Brazilian sugarcane juice pathway. A revised interim or final value for ethanol derived from pure sugarcane juice or by-product molasses in Brazil may be proposed in the near term.

On the basis of these findings, ARB staff recommends that Abengoa Bioenergia's application for a Method 2B LCFS pathway be approved with a CI of 54.92 gCO_2e/MJ of ethanol fuel produced at the São Luiz mill using by-product molasses as the only feedstock.